Intraobserver and Interobserver Reliability of Two Ultrasound Measures of Humeral Head Position in Infants with Neonatal Brachial Plexus Palsy

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Intraobserver and Interobserver Reliability of Two Ultrasound Measures of Humeral Head Position in Infants with Neonatal Brachial Plexus Palsy

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Background: Ultrasonographic evaluation of the hip in infants is considered both reliable and reproducible in the diagnosis of developmental dysplasia of the hip. Ultrasonographic evaluation of the shoulder in infants has been reported as a valuable diagnostic aid in dysplastic development following neonatal brachial plexus palsy. To our knowledge, there has been no study of the intraobserver reproducibility and interobserver reliability of sonography of the shoulder in infants with and without suspected posterior shoulder dislocation.

Methods: Two identical but randomly ordered sets of the same deidentified sonographic images of shoulders in infants were given to radiologists, pediatric orthopaedists and orthopaedic residents, and fellows with varying degrees of experience in the evaluation of shoulder pathology in infants, who measured the position of the humeral head relative to the axis of the scapula. Intraobserver reproducibility and interobserver reliability of the measurements were assessed.

Results: For the position of the humeral head with respect to the glenoid in both normal and abnormal conditions, the Pearson correlation coefficient for intraobserver reproducibility was 0.91 and the intraclass correlation coefficient for interobserver reliability was 0.875. For estimating the percentage of the humeral head posterior to the axis of the scapula, the Pearson correlation was 0.85 and the intraclass correlation coefficient was 0.77.

Conclusions: Ultrasonographic examination of the shoulder in infants to assess for the position of the humeral head with respect to the scapula showed high intraobserver reproducibility and interobserver reliability. It is recommended as a reliable technique for evaluating shoulder position in infants with neonatal brachial plexus palsy.

Posterior shoulder dislocation in infants with neonatal brachial plexus palsy is more frequent than has generally been realized. Moukoko et al. found that eleven (8%) of 134 infants who were less than one year old when first seen had a posterior shoulder dislocation[1]. Van der Sluijs et al. noted that nine of sixteen infants younger than one year with persistent brachial plexus palsy after three months of age had abnormalities of the glenohumeral joint[2]. Waters et al. suggested that it is important to be aware of the possibility of glenohumeral dislocation in infants because severe osseous deformity may develop quickly in these patients[3]. Arthrography, computerized tomography, and magnetic resonance imaging are accurate methods of diagnosis, but all require sedation of the infant. Hunter et al. suggested that ultrasonography is a safe, quick, and reliable method of excluding posterior dislocation and advocated that all neonates with brachial plexus palsy should have an ultrasound examination of the shoulder as a first-line investigation[4].

Ultrasonographic examination of the hip is widely accepted as the imaging method of choice in an infant, but the

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technique has not been widely extended to the evaluation of the shoulder[5-7]. As yet, there has been no study of the intraobserver reproducibility and interobserver reliability of ultrasonography of the shoulder in infants with and without suspected posterior shoulder dislocation.

In making clinical decisions, orthopaedic surgeons rely heavily on observations and measurements obtained from the history, physical findings, and imaging studies. A measurement is regarded as reliable, or reproducible, if the same result is obtained when the same entity is measured again[8]. The purpose of this study was to validate a sonographic measurement of the alignment of the shoulder in infants and to study the intraobserver reproducibility and interobserver reliability for two measures of glenohumeral relationship in the infant shoulder.

Materials and Methods

After receiving approval from our institutional review board, we selected thirty sonographic studies of shoulders from previously obtained electronic patient image files. All patients were under the age of one year at the time the studies had been done. The sonographic images of the shoulders were performed from the posterior approach with a technique described by Hunter et al.[4] and Grissom and Harcke[9], utilizing a linear 5 to 8-MHz multihertz transducer on the Acuson Sequoia 512 platform (division of Siemens, Mountain View, California). The shoulder sonography protocol obtains images of both the normal shoulder and the involved shoulder in resting, internally rotated, and externally rotated positions. Technicians make multiple images of each shoulder during a dynamic study. Individual images of both the normal and abnormal shoulders were selected for the overall quality of the study and the clarity of anatomic landmarks. Of the thirty images, thirteen were of the normal, contralateral shoulder of an affected infant, three were of completely dislocated shoulders with no articular surface contact, and fourteen were of shoulders that had varying degrees of subluxation but still had some articular surface contact. Two images were deliberately selected because of poor or ambiguous landmarks. All of the images were deidentified and copied as high-resolution JPEG (Joint Photographic Experts Group) format digital files.

Image files were randomly numbered and bundled as Set I and then were renumbered and bundled as Set II. Each set of images also included a digital protractor-ruler software program (MB-Ruler 3.3; Markus Bader, Iffezheim, Germany). These sonographic image sets were then given to ten observers on two separate occasions. All observers received a teaching presentation on PowerPoint (Microsoft, Redmond, Washington) with detailed instructions on how to use the measuring tool and make and record the measurements. The measurements from each participant were recorded in a Microsoft Access database (Microsoft) for later analysis. Two specific measurements were made:

SGH angle or α-angle. This is a measure of the position of the humeral head relative to the axis of the scapula. The α-angle is the angle formed by the intersection of a line along the posterior scapular margin (S) and a line tangent to the humeral head (H) passing through the posterior osseous lip of the glenoid (G) (α-angle = SGH) (Figs. 1-A and 1-B).

Posterior displacement of humeral head. This is expressed as a percentage of the humeral head that is displaced posterior to the axis of the posterior part of the scapula. The measurement is calculated by taking the distance from the posterior scapular line to the posterior margin of the head (BC), divided by the greatest diameter of the humeral head (AC), and multiplying by 100 (Figs. 2-A and 2-B). This number is then rounded to the nearest multiple of 10.

Statistical Methods

The magnitude and significance of intraobserver reliability were evaluated with use of the Pearson correlation coefficient as well as the percentiles of the absolute values of the difference between two readings by the same observer. Interobserver reliability was evaluated with use of the intraclass correlation coefficient. The percentiles of the absolute differences were used to provide a more clinically meaningful interpretation of the reliability of a measure. The Pearson correlation and intraclass correlation coefficient are included because they are the general benchmark tools for this type of study.

Results

Observers included pediatric orthopaedic surgeons, pediatric radiologists, pediatric orthopaedic fellows, hand and upper-limb surgeons, and orthopaedic residents.

Twenty-eight images were included in the statistical evaluation. The two images that had been deliberately selected for poor landmarks were not scored by over half of the observers, who commented that those images were inadequate for evaluation. This indicated that the observers understood the instructions and were comfortable identifying landmarks and assessing a scan suitable for measurement.

The α-angle of the normal, contralateral shoulder was ≤30°. The humeral head normally is centered in the glenoid. The center of the humeral head should normally sit anterior to the line along the posterior part of the scapula. The percentage of the humeral head that lies posterior to this line should therefore be <50%.

Intraobserver Results

For the SGH angle, 85.7% of the differences between two readings by an observer were ≤10° and 96.8% were ≤20°. The overall Pearson correlation for the SGH angle was 0.91, generally considered to reflect excellent intraobserver reproducibility.

For the measurement of posterior displacement of the humeral head, 92.1% of the differences between two readings by an observer were ≤10 percentage points and 96.4% were ≤20 percentage points. One observer had only fair reproducibility. The overall Pearson correlation coefficient was 0.85, or very good.

Interobserver Results

With regard to the SGH angle in Set I, 76.7% of the differ-

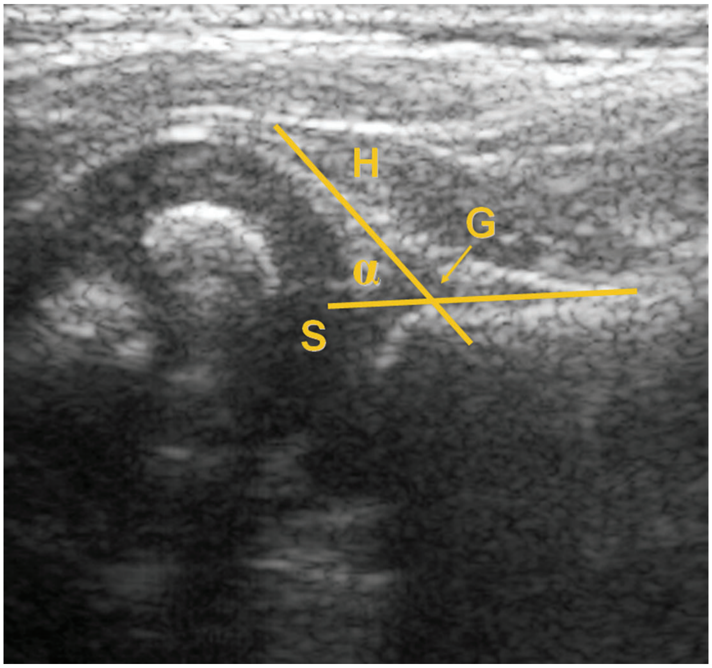

Fig. 1-A

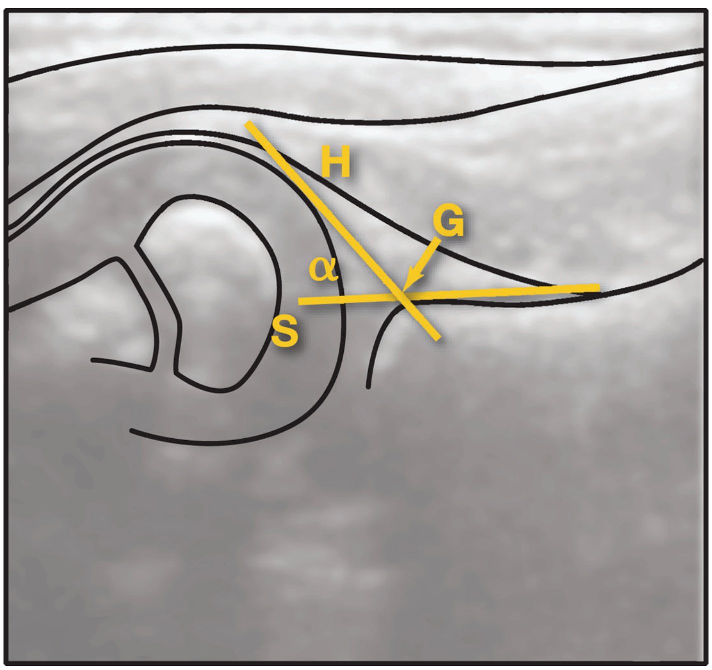

Fig. 1-B

Figs. 1-A and 1-B The first measurement was the α-angle, which is formed by the posterior scapular margin (S) and a line tangent to the humeral head (H) passing through the posterior osseous lip of the glenoid (G) (α-angle = SGH).

ences between two randomly chosen observers were <10° and 93.4% of the differences were <20°. The intraclass correlation coefficient was 0.87, indicating very good to excellent interobserver reliability. In Set II, 78.9% of the differences were <10° and 93.9% of the differences were <20°. The intraclass correlation coefficient was 0.88, indicating very good to excellent interobserver reliability. The average for the two sets was an intraclass correlation coefficient of 0.875; 77.8% of the differences were <10° and 93.7% of the differences were <20°. Note the close agreement between the results of the two sets. This indicates that there was no learning curve beyond that needed to measure the first set of images.

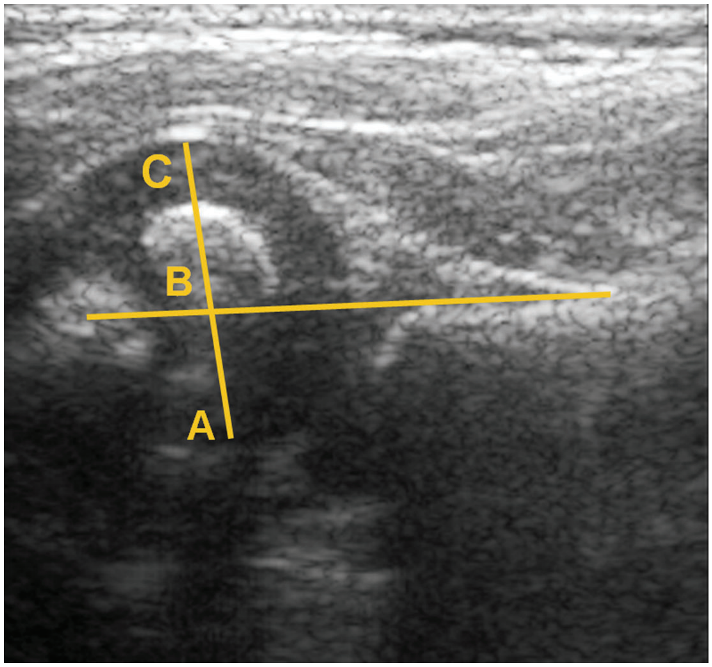

Fig. 2-A

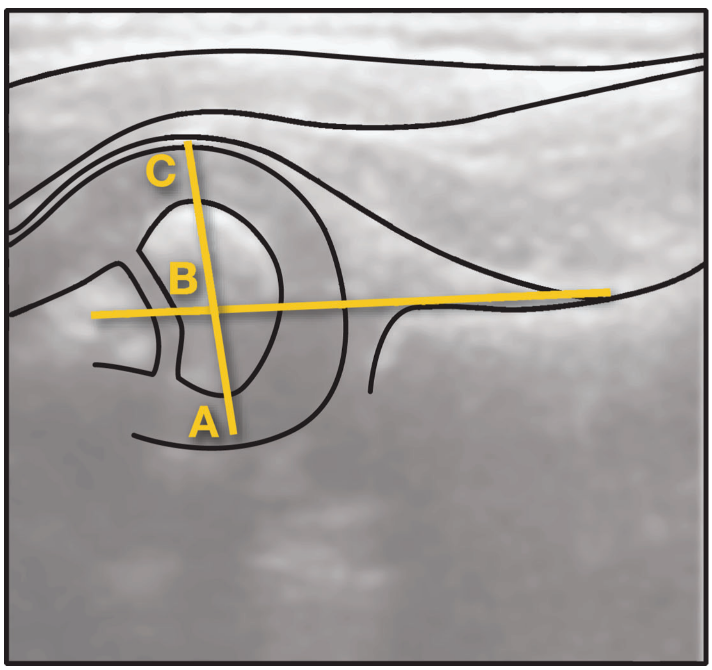

Fig. 2-B

Figs. 2-A and 2-B The second measurement was the percentage of humeral head displacement, which is posterior to the posterior scapular margin. The ratio (the distance from the posterior scapular line to the posterior margin of the head [BC] divided by the greatest diameter of the humeral head [AC] and multiplied by 100) is the percentage of posterior humeral displacement.

With regard to posterior displacement of the humeral head in Set I, 79.5% of the differences were <10% and 93.6% were <20%. The intraclass correlation coefficient was 0.77, indicating fair to good interobserver reliability. In Set II, 80.6% of the differences were <10% and 92.7% were <20%. The intraclass correlation coefficient was also 0.77. The average for the two sets was an intraclass correlation coefficient of 0.77; 80.1% of the differences were <10% and 93.5% of the differences were <20%. Note again the close agreement between the results of the two sets, indicating that there was no learning curve beyond that needed to measure the first set of images.

There was no difference in the intraclass correlation coefficient between the normal and abnormal images sent to the observers.

Discussion

Imaging of the shoulder is often done with computerized tomography or magnetic resonance imaging to best define both the osseous and soft-tissue anatomy. These techniques provide high levels of resolution of the soft tissues and are invaluable for imaging tumors, tendon abnormalities, vascularity of osseous and soft tissues, and intraosseous extension of pathologic processes. Waters et al. measured the degree of retroversion of the glenoid in children with neonatal brachial plexus palsy and found that these techniques provided excellent visualization of the immature shoulder[3]. In that series, the youngest patient was nine months of age and magnetic resonance imaging was preferred over computed tomography because of better visualization in infants with incomplete ossification of the humeral head. The average age of the patients whose images were included in our study was six months.

Grissom and Harcke reported on the use of sonography to evaluate the shoulder in infants, and they defined the sonographic anatomy from various approaches, including the posterior approach[9]. In patients ranging in age from three days to nine months and including those with normal shoulders as well as those being evaluated for trauma, infection, tumor, and neonatal brachial plexus palsy, there was a relative limitation of the ultrasound because of painful conditions in some patients.

In our institution, we prefer ultrasonography for imaging of the shoulder in infants because of the detail that can be obtained when the humeral head has not yet ossified. The position of the humeral head is measured by the angle formed by the intersection of a line through the axis of the scapula and a line tangent to the posterior aspect of the humeral head at the posterior osseous lip of the glenoid. These landmarks can be easily and reproducibly identified on sonographic images from the posterior approach. This is a different measurement from that used in the study by Waters et al., in which the measurement of glenoid version required clear visualization of the anterior lip of the osseous glenoid[3]. The anterior aspect of the glenoid cannot be well visualized by sonography, which is a weakness of this technique.

Wright and Feinstein suggested use of the term *clinician variability* rather than observer variability to describe those elements leading to either the same or a different result on measuring the same entity[8]. These elements include familiarity with the process and technique for measurement, the ability to identify landmarks, the ability to manipulate the measuring tools, and nontechnical factors such as the level of fatigue, time between measuring the sets of images, or time since the review of the instruction materials. In this study, the instructional materials sent with each set of images provided a step-by-step, detailed series of instructions for measuring each of these two sets of images. An electronic measuring tool was used rather than a paper-and-pencil or protractor method because imaging methods are currently acquired and manipulated in digital format. The conversion to JPEG format was done to facilitate the accession of images by the observers and to ensure deidentification of the images. Additional blinding was provided by scrambling the sequence of images between the sets.

Ultrasonography has become the standard technique for evaluating infants suspected of having developmental dysplasia of the hip. The use of this technique to image the shoulder in an infant with brachial plexus palsy has the advantage of being cost-effective and it requires no sedation or fasting. Sonography is readily accepted by parents who have most likely experienced the technique as a routine surveillance procedure during pregnancy. The examination is most often done with the child held on the mother's shoulder, and a dynamic study can be obtained with no discomfort to the child. During this study, passive external rotation of the shoulder may demonstrate whether the humeral head can be reduced or whether it lies in a fixed dislocated position. Parents can visualize the difference between the normal and abnormal side, and this helps them to understand the structural changes that may have occurred in their child's shoulder.

The disadvantage of this technique of sonographic imaging is the inability to clearly define the anatomy of the anterior glenohumeral joint even in infants, and the images obtained are not as detailed as those produced by magnetic resonance imaging or computed tomography. This, however, does not affect one's ability to determine the congruency of the humeral head with respect to the posterior aspect of the glenoid and thereby detect early subluxation and glenoid deformity. Because ossification of the humeral head obscures the anatomy anterior to the humeral head, the usefulness of the technique decreases with age and maturation of the osseous skeleton.

Ultrasonography, like any other imaging technique, is dependent on the technical skills of the one performing the examination and the interpretation of the observer. It will not supplant magnetic resonance imaging or computed tomography in defining the shoulder joint, but it does add another imaging tool that is readily learned and used by radiologists and orthopaedists familiar with ultrasonography of the hip. We recommend ultrasonography of the shoulder as a valuable screening tool for infants with neonatal brachial plexus palsy under the age of one year who are at risk for posterior subluxation or dislocation of the shoulder. ■

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